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The origins of turbulent flow and the transition from laminar to turbulent flow are among the most important unsolved problems of fluid mechanics and aerodynamics. Besides being a fundamental question of fluid mechanics, there are any number of applications for information regarding transition location and the details of the subsequent turbulent flow. The IUTAM Symposium on Laminar-Turbulent Transition, Co-hosted by Arizona State University and the University of Arizona, was held in Sedona, Arizona. Although four previous IUTAM Symposia bear the same appellation (Stuttgart 1979, Novosibirsk 1984, Toulouse 1989, and Sendai 1994) the topics that were emphasized at each were different and reflect the evolving nature of our understanding of the transition process.

The Sedona 1999 meeting focussed almost exclusively on open systems, and as such, on wall-bound shear flows. The major impact topics were receptivity of initial disturbances, crossflow instabilities, supersonic flows, and control of transition. Many papers were on combined numerical and experimental work. The objectives of many of these studies were to properly define the fundamental physics of the stability and transition process. As a consequence, this fundamental knowledge now enables different techniques of transition control and its subsequent decrease in drag. One expects increased emphasis on this topic in the future.

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Final Report

for

Symposium Grant
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by

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IUTAM SYMPOSIUM: "LAMINAR-TURBULENT TRANSITION"

Sedona, Arizona
September 13-17, 1999

Dr. Thomas L. Doligalski, Chief
Fluid Dynamics Branch
Engineering Sciences Division
U.S. Army Research Office

December 2000

Final Report

IUTAM[1] Symposium: "Laminar-Turbulent Transition"

Introduction and Summary

The origins of turbulent flow and the transition from laminar to turbulent flow are among the most important unsolved problems of fluid mechanics and aerodynamics. Besides being a fundamental question of fluid mechanics, there are any number of applications for information regarding transition location and the details of the subsequent turbulent flow.

The IUTAM Symposium on Laminar-Turbulent Transition, co-hosted by Arizona State University and the University of Arizona, was held in Sedona, Arizona. Although four previous IUTAM Symposia bear the same appellation (Stuttgart 1979, Novosibirsk 1984, Toulouse 1989, and Sendai 1994) the topics that were emphasized at each were different and reflect the evolving nature of our understanding of the transition process.

The major contributions of Stuttgart 1979 centered on nonlinear behavior and later stages of transition in two-dimensional boundary layers. Stability of closed systems was also included with Taylor vortices in different geometries. The topics of Novosibirsk 1984 shifted to resonant wave interactions and secondary instabilities in boundary layers. Pipe- and channel-flow transition were discussed as model problems for the boundary layer. Investigations of free shear layers were presented and a heavy dose of supersonic papers appeared for the first time. The character of Toulouse 1989 was also different in that 3-D boundary layers, numerical simulations, streamwise vortices, and foundation papers on receptivity were presented. Sendai 1994 saw a number of papers on swept wings and 3-D boundary layers. Numerical simulations attacked a broader range of problems.

The Sedona 1999 meeting focussed almost exclusively on open systems, and as such, on wall-bounded shear flows. The major impact topics were receptivity of initial disturbances, crossflow instabilities, supersonic flows, and control of transition. More papers appeared on combined numerical and experimental work. In other cases, teams from different institutes combined resources to solve complicated problems. The objectives of many of these studies were to properly define the fundamental physics of the stability and transition process. One can track certain freestream disturbances that provide the initial conditions for unstable waves in somewhat complicated geometries. As a consequence, this fundamental knowledge now enables different techniques of transition control and its subsequent decrease in drag. One expects increased emphasis on this topic. Papers on transient growth and sub-critical development of 3-D disturbances pointed to future areas of research.

All in all, the Symposium was an all-out success. An indication of this success is the high quality of the papers presented and published in the proceedings (a copy of which is enclosed).

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[1] International Union for Theoretical and Applied Mechanics.

Symposium Topics

Emphasis of the Symposium was on stability and transition of both incompressible and compressible flows. Specifically, the following topics were addressed:

1. Effect of free-stream disturbances that lead to transition.

2. Role of large-amplitude initial conditions.

3. Transient growth problems and bypasses of Orr-Sommerfeld mechanisms.

4. Processes from nonlinear dynamical systems that influence transition.

5. Later stages of transition and breakdown to turbulence.

6. Control of boundary-layer transition.

Symposium Location/Date: Sedona, Arizona, September 13-17, 1999

The timing was ideal for such a symposium. The previous IUTAM-Symposium on laminar-turbulent transition was held in September 1994 (Sendai, Japan). Considerable progress has been made in this field over the past 5 years, due to the fact that this research topic has received increased attention worldwide, particularly in Europe. Major advances in computational sciences, high-performance computing hardware, and high-tech diagnostics equipment for experimental research have contributed to major advances in the field. Thus, this was an excellent time for the experts in this research area to come together and discuss their progress.

Relation of Conference Topic to Research Interests of ARO

Laminar-turbulent transition occurs in the external flows of all flight vehicles, i.e., airplanes, helicopters, rockets, missiles, projectiles, etc. The location of transition and the transition process itself have a major influence on the performance of flight vehicles. Transition is associated with drastically increased drag and, as a consequence, impacts range, power plant requirements, and the fuel needed to complete a mission. Further, for high-speed flows, such as in rockets, missiles, projectiles, and supersonic/hypersonic aircraft, the high temperatures associated with transition causes considerable heat loads on the system, requiring extensive and costly heat-shielding materials, which leads to heavy load penalties. In addition, transition influences the separation behavior of external flows and, as such, the entire stability and performance of flight vehicles.

Laminar-turbulence transition also plays a major role in internal flows. Combustion (for turbines) and cooling of components (for example, electronics) are greatly enhanced in transitional and turbulent flows. Thus, accelerating transition would be beneficial in such applications.

It is important to note that the keynote speaker for the conference was Dr. L. Mack, Jet Propulsion Laboratory, who is ***the*** world expert on ***compressible*** transition. Several papers were presented on compressible transition. This is of great relevance to ARO, as most Army technical applications involve compressible flows, both high subsonic (over part of the rotor in rotorcraft flight vehicles) and supersonic (missiles, rockets, projectiles).

Attendees

The represented countries and numbers of participants were as follows:

Countries Represented and Number of Participants

Australia	1	Brazil	1	Canada	2
China	2	France	7	Germany	24
Greece	1	India	2	Israel	1
Italy	1	Japan	15	Russia	11
Sweden	2	Switzerland	3	The Netherlands	1
U.K.	16	Ukraine	1	USA	42

Total participants: 132

Symposium Sponsors

The organization of the symposium would not have been possible without the funding from several sponsors, which are listed below.

International Union of Theoretical and Applied Mechanics (IUTAM)
Arizona State University
University of Arizona
ASU Unsteady Wind Tunnel
UA Computational Fluid Dynamics Laboratory
Army Research Office
Office of Naval Research
National Science Foundation
Air Force Office of Scientific Research

Organization of Symposium

The organizational structure of the Symposium was as follows:

Scientific Committee

W. Saric (Co-Chair) (USA)
H. Fasel (Co-Chair) (USA)
D. Arnal (France)
P. Baines (Australia)
H. Bippes (Germany)
M. Gaster (UK)
R. Kobayashi (Japan)
V. Koslov (Russia)
V. Levchenko (Russia)
R. Narasimha (India)
T. Tatsumi (Japan)
J. van Ingen (Netherlands)
H. Zhou (China)

Local Organizing Committee

H. Fasel (Univ. of Arizona)
E. Kerschen (Univ. of Arizona)
H. Reed (Arizona State Univ.)
E. Reshotko (Case Western Univ.)
W. Saric (Arizona State Univ.)
I. Wygnanski (Univ. of Arizona)

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